Supporting Information for

Forest carbon gains from environmental and management changes reduce conversion pressure on natural land

Meng Luo[1], Adam Daigneault[2], Dalei Hao[3], Xin Zhao[4, 5], Alice Favero[6], Christopher P.O. Reyer[7], Akihiko Ito[8], Sian Kou-Giesbrecht[9], Qing Zhu[10], Brent Sohngen[11], Min Chen[1*]

[1]Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, United States of America.

[2]School of Forest Resources, University of Maine, United States of America.

[3]Atmospheric, Climate, & Earth Sciences Division, Pacific Northwest National Laboratory, United States of America.

[4]Joint Global Change Research Institute, Pacific Northwest National Laboratory, United States of America.

[5]Center for Global Sustainability, School of Public Policy, University of Maryland, College Park, Maryland, United States of America.

[6] RTI International, Center for Applied Economics and Strategy, 3040 E Cornwallis Rd, Durham, NC, United States of America.

[7] Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Germany.

[8] Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo, 113-8657, Japan.

[9]School of Resource and Environmental Management, Simon Fraser University, Canada

[10] Climate and Ecosystem Sciences Division, Lawrence Berkeley National Lab, Berkeley, CA 94720, United States of America.

[11] Department of Agricultural, Environmental and Development Economics, the Ohio State University, Columbus, OH, United States of America.

Corresponding author: Min Chen (min.chen@wisc.edu)

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Text S1. Impacts of Terrestrial Biosphere Model (TBM) and climate forcing uncertainty in forest carbon stocks and land use simulations

S1.1. Forest vegetation, soil carbon, and total carbon stocks

For forest vegetation carbon stocks under the combined effect of environmental changes and forest management (Envir_Manage), the Vegetation Integrative Simulator for Trace gases (VISIT) simulations driven by different climate forcings — the Geophysical Fluid Dynamics Laboratory Earth System Model version 4 (GFDL), the United Kingdom Earth System Model version 1-0-LL (UKESM), the Institute Pierre-Simon Laplace Climate Model version 6A–Low Resolution (IPSL), the Max Planck Institute Earth System Model version 1.2–High Resolution (MPI), and the Meteorological Research Institute Earth System Model version 2.0 (MRI) — show a consistent global increasing trend under both SSP126 and SSP585 (Fig. 1b,d). Differences across climate forcings are primarily in magnitude rather than direction, and spatial patterns are generally more consistent under SSP585 than under SSP126 across climate forcings (Fig. S7). A similar level of consistency across forcings is found for the environmental (Envir_only) and forest management (Manage_only) effects (Fig. 1f,h,j,l). Across VISIT simulations and VISIT-driven GTM simulations, the combined effect also shows similar temporal trends in total forest carbon stocks (vegetation + soil), again with differences primarily in magnitude. In contrast to vegetation carbon stocks, the direction of soil carbon stock changes is less consistent across forcings (Fig. S17), in line with the relatively higher uncertainty in soil carbon stock responses reported in previous studies[1–3].

Across TBMs, the global patterns of forest carbon stock changes are similar, but VISIT typically produces larger increases in forest vegetation carbon stocks than the Canadian Land Surface Scheme Including Biogeochemical Cycles (CLASSIC), especially under SSP126 (Fig. S5). These TBM differences reflect their environmental change–induced forest carbon changes: VISIT simulates an overall larger increase (or smaller decrease) in total forest carbon than CLASSIC, for both vegetation and soil carbon densities (Figs. 1 and S3–S4). In CLASSIC simulations, declines in soil carbon can partially offset vegetation gains, leading to small net decreases in total forest carbon when only the environmental change effect is considered, particularly under SSP585. When management effects are included, however, the combined effect leads to a net increase in total forest carbon under SSP126 (Fig. S5), underscoring the importance of forest management, especially in a world with relatively low CO_2 fertilisation.

S1.2. Natural land area changes

For the combined effect of environmental changes and forest management (Envir_Manage), GCAM land use projections driven by VISIT simulations under different climate forcings (GFDL, UKESM, IPSL, MPI, MRI) show broadly similar global trends in total natural land change under both SSP126 and SSP585 (Fig. S15a,e). At the level of individual land use types, the direction of change is also generally consistent across forcings (Table S4; Figs. S18–S19). For the individual effects (environmental changes, forest management, and their interaction), VISIT-based simulations driven by different climate forcings show similar trends in total natural land change and generally consistent changes across detailed land use types under both SSP126 and SSP585 (Fig. S15b–d,f–h; Table S3). The spread in magnitude across forcings is largest for the environmental change effect, which is expected given its larger overall contribution to land use change relative to the management and interaction effects.

When comparing across TBMs, total natural land exhibits broadly similar trajectories for the combined effect and each individual driver (Fig. S14j–l,n–p), but differences become more pronounced for detailed unmanaged types, particularly under SSP126 when driven by environmental changes. By 2100, the combined effect on unmanaged forest area is negative in CLASSIC-based simulations (-51.8 and -39.6 thousand km^2), in contrast to the positive changes in VISIT-based simulations (503.1 to 916.3 thousand km^2; Table S4). This is mainly due to the notable difference in the environmental effect between CLASSIC-based simulations and VISIT-based simulations. By 2100, the environmental change effect on unmanaged forest area is negative in CLASSIC (-160.9 and -159.6 thousand km^2), in contrast to the positive changes simulated by VISIT (379.4 to 797.5 thousand km^2; Table S4).

These differences are closely linked to the environmental change–induced forest carbon stock changes simulated by the two TBMs. For environmental change–induced forest carbon change, VISIT simulates an overall larger increase (or smaller decrease) in total forest carbon than CLASSIC, for both vegetation carbon stocks and soil carbon stocks (Figs. 1 and S4–S6). In CLASSIC simulations, total forest carbon under environmental changes can show a small net decrease, largely driven by declines in soil carbon that are only partly compensated by modest vegetation carbon gains. In contrast, VISIT generally produces net increases in both vegetation and soil carbon. These larger forest carbon gains in VISIT translate into correspondingly larger increases (and, in some cases, increases rather than decreases) in natural land, especially unmanaged forest, under both Envir_only and Envir_Manage. Across all TBM simulations, managed forest consistently shows the largest relative decrease in area, providing the main source of land for natural land expansion.

Text S2. Mechanisms behind the interaction between environmental change and forest management on forest vegetation carbon stocks

The contrasting direction of interaction effects between environmental change and forest management on forest vegetation carbon stock changes under SSP126 and SSP585 (Fig. 1d,h) arises from two mechanisms: the direct impact of environmental changes on forest vegetation carbon stocks and the influence of carbon price. Environmental change generally increases forest vegetation carbon stocks under both SSP126 and SSP585. This increase tends to lower roundwood prices, substituting for human inputs that intensify forest management. At the same time, the presence of a carbon price can incentivize additional forest management regardless of whether environmental change occurs[4–7]. The net outcome of these mechanisms differs across the two scenarios. Under SSP126, a relatively high carbon price outweighs the moderate decrease in roundwood prices induced by environmental changes. This results in stronger incentives for investment in forest management, ultimately amplifying the forest vegetation carbon stock gains driven by forest management practices. In contrast, under SSP585, carbon prices are much lower, and the environmental change-induced decrease in roundwood price plays a dominant role. This price decrease reduces incentives for forest management investment and thus suppresses the forest vegetation carbon stock gains that would otherwise result from enhanced forest management. These interactions reflect a form of adaptation to environmental changes, driven by shifts in both forest management strategies and market responses.

Text S3. Mechanisms linking forest carbon stock changes to natural land expansion

The relative increase in the natural land driven by forest carbon stocks increase, especially unmanaged forest and pasture, accompanied by a strong decrease in managed forest, can be attributed to several mechanisms: First, environmental- and management-induced changes in forest carbon stocks directly influence land allocation. Increases in forest vegetation carbon stocks raise forest yield, which lowers roundwood prices and reduces the profitability of managed forests, leading to their contraction. At the same time, higher total forest carbon stocks (both vegetation and soil carbon stocks), combined with carbon pricing under climate policy, increase the profitability of unmanaged forests by raising the monetary value of stored carbon and result in their expansion. Because carbon pricing values both vegetation and soil carbon stock, we explicitly consider changes in both in the study. Second, these changes alter the land competition with other land use types. In our cases, the land lost from managed forest is greater than the land gained by unmanaged forest, which reduces overall land competition and allows cropland, pasture, and other uses to expand. Compared with natural land types, managed land types face declining profitability due to greater land availability, which increases the supply of crops and fodder and further suppresses prices and profits. This results in a larger relative increase in unmanaged land than in managed land (among non-forest types) and also drives a greater increase in unmanaged forest area.

Table S1. Country to region mapping in GCAM.

GCAM regions	Countries
Africa_Eastern	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Reunion, Rwanda, Sudan, Somalia, Uganda
Africa_Northern	Algeria, Egypt, Western Sahara, Libya, Morocco, Tunisia
Africa_Southern	Angola, Botswana, Lesotho, Mozambique, Malawi, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe
Africa_Western	Benin, Burkina Faso, Central African Republic, Cote d'Ivoire, Cameroon, Democratic Republic of the Congo, Congo, Cape Verde, Gabon, Ghana, Guinea, Gambia, Guinea-Bissau, Equatorial Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Sao Tome and Principe, Chad, Togo
Argentina	Argentina
Australia_NZ	Australia, New Zealand
Brazil	Brazil
Canada	Canada
Central America and the Caribbean	Aruba, Anguilla, Netherlands Antilles, Antigua & Barbuda, Bahamas, Belize, Bermuda, Barbados, Costa Rica, Cuba, Cayman Islands, Dominica, Dominican Republic, Guadeloupe, Grenada, Guatemala, Honduras, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Montserrat, Martinique, Nicaragua, Panama, El Salvador, Trinidad and Tobago, Saint Vincent and the Grenadines
Central Asia	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan
China	China
Colombia	Colombia
EU-12	Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, Slovenia
EU-15	Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Greenland, Ireland, Italy, Luxembourg, Monaco, Netherlands, Portugal, Sweden, Spain, United Kingdom
Europe_Eastern	Belarus, Moldova, Ukraine
European Free Trade Association	Iceland, Norway, Switzerland
Europe_Non_EU	Albania, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Serbia, Turkey
India	India
Indonesia	Indonesia
Japan	Japan
Mexico	Mexico
Middle East	United Arab Emirates, Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Yemen
Pakistan	Pakistan
Russia	Russia

South Africa	South Africa
South America_Northern	French Guiana, Guyana, Suriname, Venezuela
South America_Southern	Bolivia, Chile, Ecuador, Peru, Paraguay, Uruguay
South Asia	Afghanistan, Bangladesh, Bhutan, Sri Lanka, Maldives, Nepal
Southeast Asia	American Samoa, Brunei Darussalam, Cocos (Keeling) Islands, Cook Islands, Christmas Island, Fiji, Federated States of Micronesia, Guam, Cambodia, Kiribati, Lao Peoples Democratic Republic, Marshall Islands, Myanmar, Northern Mariana Islands, Malaysia, Mayotte, New Caledonia, Norfolk Island, Niue, Nauru, Pacific Islands Trust Territory, Pitcairn Islands, Philippines, Palau, Papua New Guinea, Democratic Peoples Republic of Korea, French Polynesia, Singapore, Solomon Islands, Seychelles, Thailand, Tokelau, Timor Leste, Tonga, Tuvalu, Viet Nam, Vanuatu, Samoa
South Korea	South Korea
USA	United States

Table S2. Land use area change difference by driver and scenario. Values are shown as mean ± standard deviation across VISIT simulations driven by five different Earth System Model (ESM) climate forcings. Changes are reported as both relative differences (%) and absolute differences (thousand km^2) for combined, environmental, management, and interaction effects. Note that Grass and Shrubs are both natural land, and there is no managed Grass or Shrubs category in GCAM.

		Combined effect		Environmental change effect		Forest management change effect		Interaction effect	
Scenarios	Land use types	Relative difference	Absolute difference	Relative difference	Absolute difference	Relative difference	Absolute difference	Relative difference	Absolute difference
SSP126	Managed forest	-10.6%±0.7%	-1043.3±65.2	-6.1%±0.5%	-602.4±52.3	-3.1%±0.1%	-309.5±12.2	-1.3%±0.4%	-131.4±38.5
	Unmanaged forest	2.9%±0.6%	704.3±153.8	2.4%±0.7%	582.3±155.3	0.5%±0.0%	109.6±4.1	0.1%±0.0%	12.4±10.7
	Managed pasture	-0.2%±0.1%	-10.7±7.6	-0.3%±0.1%	-13.3±7.0	0.0%±0.0%	1.9±0.9	0.0%±0.0%	0.7±0.8
	Unmanaged pasture	1.0%±0.3%	249.5±71.0	0.3%±0.3%	83.6±66.0	0.3%±0.0%	88.4±4.4	0.3%±0.1%	77.5±15.5
	Cropland	0.3%±0.2%	36.3±22.1	0.1%±0.2%	15.2±21.7	0.2%±0.0%	22.2±0.6	0.0%±0.0%	-1.2±2.5
	Bioenergy	-0.1%±0.1%	-2.5±2.4	-0.3%±0.1%	-7.6±2.3	0.0%±0.0%	1.3±0.2	0.1%±0.0%	3.8±1.2
	Grass	0.3%±0.5%	59.3±99.6	-0.2%±0.5%	-29.8±98.1	0.3%±0.0%	58.8±2.0	0.2%±0.0%	30.4±6.9
	Shrubs	0.1%±0.2%	7.0±17.8	-0.2%±0.2%	-28.0±18.0	0.2%±0.0%	27.3±1.7	0.1%±0.0%	7.7±3.1
	Others	0.0%±0.0%	0.0±0.0	0.0%±0.0%	0.0±0.0	0.0%±0.0%	0.0±0.0	0.0%±0.0%	0.0±0.0
	Total natural land	4.1%±0.4%	1009.5±51.5	2.1%±0.4%	594.8±36.4	1.4%±0.1%	285.9±11.4	0.6%±0.2%	128.7±35.6
SSP585	Managed forest	-27.1%±1.7%	-2935.0±182.7	-25.2%±1.9%	-2723.5±206.7	-4.2%±0.1%	-457.9±6.6	2.3%±0.2%	246.5±25.9
	Unmanaged forest	5.0%±0.3%	1039.7±69.2	4.5%±0.4%	939.2±80.7	0.9%±0.0%	196.5±4.5	-0.5%±0.1%	-96.1±11.7
	Managed pasture	-1.0%±0.0%	-104.9±5.0	-0.9%±0.0%	-101.8±4.8	-0.1%±0.0%	-9.4±1.1	0.1%±0.0%	6.3±0.9
	Unmanaged pasture	4.3%±0.2%	979.9±53.2	4.1%±0.3%	933.8±57.9	0.5%±0.0%	116.8±1.8	-0.3%±0.0%	-70.8±5.9
	Cropland	1.5%±0.1%	210.4±11.4	1.4%±0.1%	199.8±12.4	0.2%±0.0%	27.9±0.6	-0.1%±0.0%	-17.3±1.7
	Bioenergy	2.8%±0.4%	56.6±8.7	2.8%±0.4%	56.4±8.5	0.2%±0.0%	3.2±0.2	-0.2%±0.0%	-3.0±0.2
	Grass	3.1%±0.2%	547.0±41.8	2.9%±0.3%	506.9±46.5	0.5%±0.0%	87.4±0.8	-0.3%±0.0%	-47.3±4.7
	Shrubs	1.9%±0.2%	206.2±19.8	1.7%±0.2%	189.1±22.1	0.3%±0.0%	35.5±0.5	-0.2%±0.0%	-18.3±2.1
	Others	0.0%±0.0%	0.0±0.0	0.0%±0.0%	0.0±0.0	0.0%±0.0%	0.0±0.0	0.0%±0.0%	0.0±0.0
	Total natural land	13.4%±0.9%	2667.9±178.1	12.3%±1.1%	2467.2±201.1	2.2%±0.0%	426.8±7.0	-1.2%±0.1%	-226.1±24.3

Table S3. Natural land area change (thousand km^2) by TMB simulation and driver. Results are disaggregated by natural land type (unmanaged forest, unmanaged pasture, grass, shrub), TBM–ESM combination, scenario (SSP126, SSP585), and effect (combined, environmental, management, interaction).

Natural land types	TBM simulations	SSP126				SSP585			
		Combined	Environmental	Management	Interaction	Combined	Environmental	Management	Interaction
Unmanaged forest	CLASSIC_GFDL	-39.6	-160.9	112.5	8.8	900.1	769.2	205.1	-74.3
	CLASSIC_UKESM	-51.8	-159.6	105.8	2.1	1231.3	1115.7	197.4	-81.9
	VISIT_GFDL	763.1	632.2	106.3	24.7	1021.7	912.6	194.8	-85.7
	VISIT_UKESM	503.1	379.4	104.3	19.4	954.2	839.0	199.4	-84.2
	VISIT_IPSL	628.8	503.3	111.1	14.4	1002.8	901.1	200.1	-98.5
	VISIT_MPI	916.3	797.5	113.9	5.0	1097.0	1011.2	198.8	-113.1
	VISIT_MRI	710.2	599.2	112.5	-1.5	1122.7	1032.2	189.4	-99.0
Unmanaged pasture	CLASSIC_GFDL	332.5	199.4	89.5	43.6	793.8	727.7	122.5	-56.4
	CLASSIC_UKESM	432.4	300.5	88.8	43.0	1030.1	965.1	122.3	-57.3
	VISIT_GFDL	267.3	85.3	82.6	99.4	989.9	939.0	115.4	-64.6
	VISIT_UKESM	345.7	182.2	86.1	77.5	935.1	882.2	118.8	-65.9
	VISIT_IPSL	262.6	89.2	88.5	84.9	915.5	868.1	117.5	-70.1
	VISIT_MPI	151.7	-1.3	90.7	62.3	1021.3	982.0	118.1	-78.8
	VISIT_MRI	220.4	62.8	94.1	63.5	1037.7	997.7	114.4	-74.4
Grass	CLASSIC_GFDL	190.2	111.2	58.9	20.1	456.4	403.9	91.7	-39.2
	CLASSIC_UKESM	317.0	239.0	58.2	19.8	653.7	604.6	89.6	-40.5
	VISIT_GFDL	35.4	-61.4	57.3	39.5	531.2	486.1	87.7	-42.7
	VISIT_UKESM	181.5	93.3	56.7	31.6	499.4	454.5	88.6	-43.6
	VISIT_IPSL	118.5	26.3	58.3	33.9	524.4	483.3	86.7	-45.6
	VISIT_MPI	-83.8	-167.9	60.5	23.6	578.8	544.9	87.0	-53.1
	VISIT_MRI	44.9	-39.6	61.1	23.3	601.5	565.9	86.9	-51.4
Shrubs	CLASSIC_GFDL	54.9	21.0	29.8	4.1	182.0	159.3	37.5	-14.8
	CLASSIC_UKESM	91.5	57.9	26.5	7.1	244.8	224.6	36.0	-15.7
	VISIT_GFDL	6.5	-31.1	26.3	11.3	196.7	177.9	35.5	-16.6
	VISIT_UKESM	37.0	2.7	25.3	9.0	184.0	164.0	36.3	-16.4
	VISIT_IPSL	-1.0	-37.7	27.3	9.4	196.6	179.2	35.1	-17.7
	VISIT_MPI	-9.8	-43.5	29.8	4.0	222.6	208.2	35.3	-20.9
	VISIT_MRI	2.4	-30.4	27.7	5.0	231.2	216.2	35.2	-20.1

Table S4. Plant functional type harmonization between TBMs and GCAM.

CLASSIC land types	**Harmonization of land types Between CLASSIC and GCAM**	**GCAM land types**	**Harmonization of land types between VISIT and GCAM**	**VISIT land type**
C3crop	C3crop	FiberCrop, FodderHerb, FruitsTree, Fruits, Legumes, MiscCropTree, MiscCrop, NutsSeedsTree, NutsSeeds, OilCropTree, OilCrop, OilPalmTree, OtherArableLand, OtherGrain, Rice, RootTuber, Soybean, Vegetables, Wheat, biomassTree, SugarCrop	Crop	Crop
C4crop	C4crop	biomassGrass, OtherGrainC4, CornC4, SugarCropC4, FodderHerbC4		
Grass	Pasture	Pasture, ProtectedUnmanagedPasture, UnmanagedPasture,	Grass	tibetan meadow & siberian highland, warm or hot wetlands, cool bog & mire, shore & hinterland, second growth field, second growth woods, succulent & thorn wood, tropical savanna, woodland
	Grass	FodderGrass, Grassland, ProtectedGrassland		
	Shrubland	ProtectedShrubland, Shrubland	Shrub	mediterranean-type dry wood, cool semi-desert scrub
Needleleaf evergreen tree, Needleleaf deciduous tree, Broadleaf evergreen tree, Broadleaf cold deciduous tree, Broadleaf drought deciduous tree	Forest	Forest	Forest	tropical montane Forest, tropical & subtropical dry Forest, mid-latitude mixed Forest, mid-latitude broad-leaved Forest, semiarid wood or low Forest, coniferous evergreen Forest, southern taiga, main evergreen taiga, main deciduous taiga, northern evergreen taiga, northern deciduous taiga

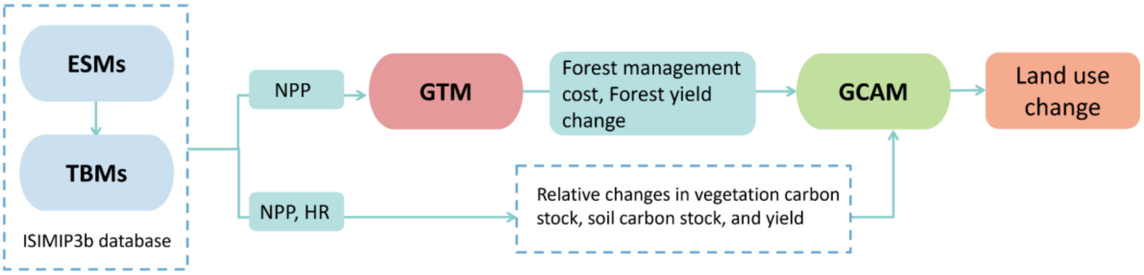

Fig. S1. Flowchart of the full coupling framework applied in the study, corresponding to the Envir_Manage experiment. Outputs from Earth System Models (ESMs) and Terrestrial Biosphere Models (TBMs) in the ISIMIP3b database provide net primary productivity (NPP) and heterotrophic respiration (HR) to represent the impacts of environmental change on vegetation and soil carbon. Forest yield and management cost responses are simulated using GTM, with woody biomass inputs derived from GCAM. Relative changes in vegetation carbon stock, soil carbon stock, and yields of all vegetation types are then incorporated into GCAM to project land use change. Note that in the Baseline experiment, only relative changes in vegetation carbon stocks, soil carbon stocks, and yields of non-forest vegetation are incorporated into GCAM. Additionally, a consistent carbon price is applied in both GTM and GCAM to ensure scenario consistency. This framework represents the fully coupled configuration among ESMs, TBMs, GTM, and GCAM. Other experiments use reduced or partial couplings (see Methods for details).

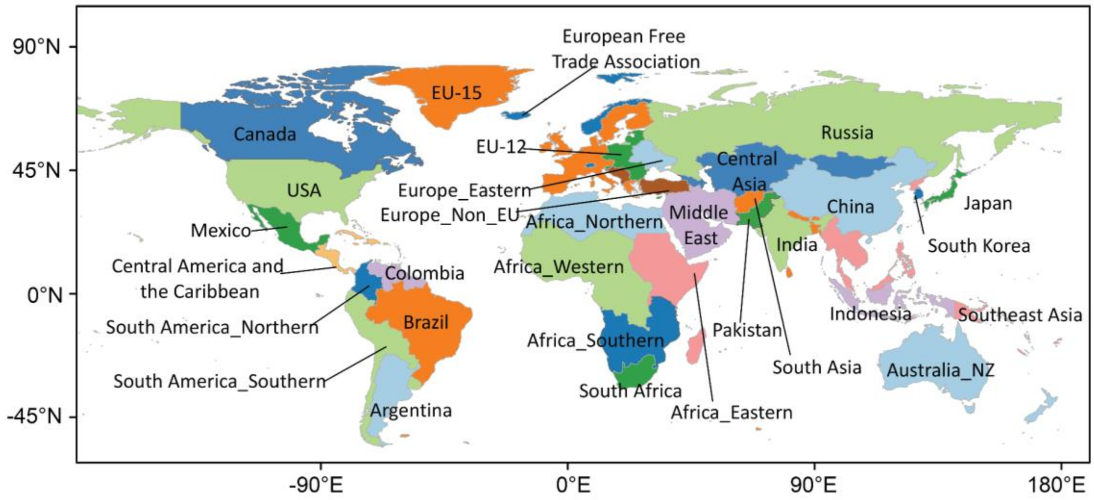

Fig. S2. Spatial distribution of GCAM regions, adapted from Calvin et al. (2019). Distinct colours are used to distinguish adjacent regions. Map lines delineate study areas and do not necessarily represent accepted national boundaries.

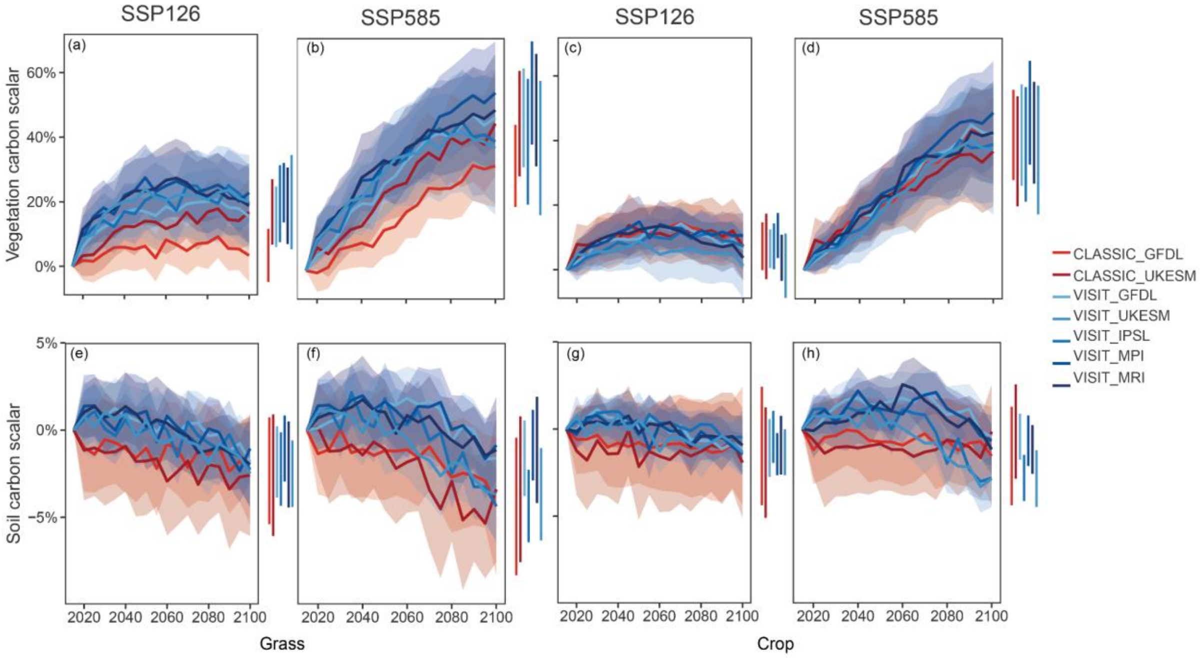

Fig. S3. Relative change in vegetation and soil carbon stocks for grass and crop from 2015–2100. Panels (a,b,e,f) show grass; panels (c,d,g,h) show crop. Left panels show SSP126; right panels show SSP585. Grass and crop categories follow the harmonized PFT-to-GCAM classification in Table S4. Shaded areas indicate spatial variability (standard deviation) across GCAM regions. Error bars represent spatial variability across GCAM regions, calculated from the 2098–2100 mean. Because 2100 is the final model year, this period constitutes the only available centered moving-average window for 2100 at a 5-year time step (see Methods).

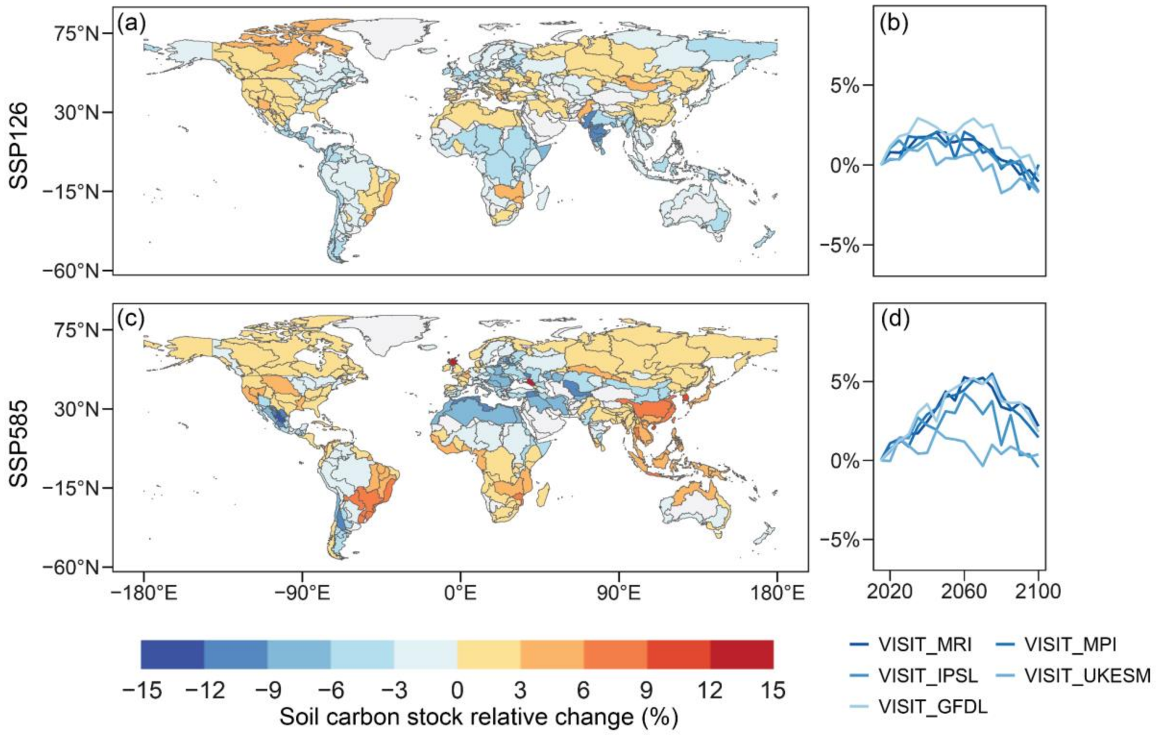

Fig. S4. Forest soil carbon scalar change from 2015–2100. Panels (a,c) show spatial patterns; panels (b,d) show temporal trends. Top row: SSP126; bottom row: SSP585. Line colours represent VISIT simulations driven by different ESM climate forcings. Solid lines show global area-weighted means.

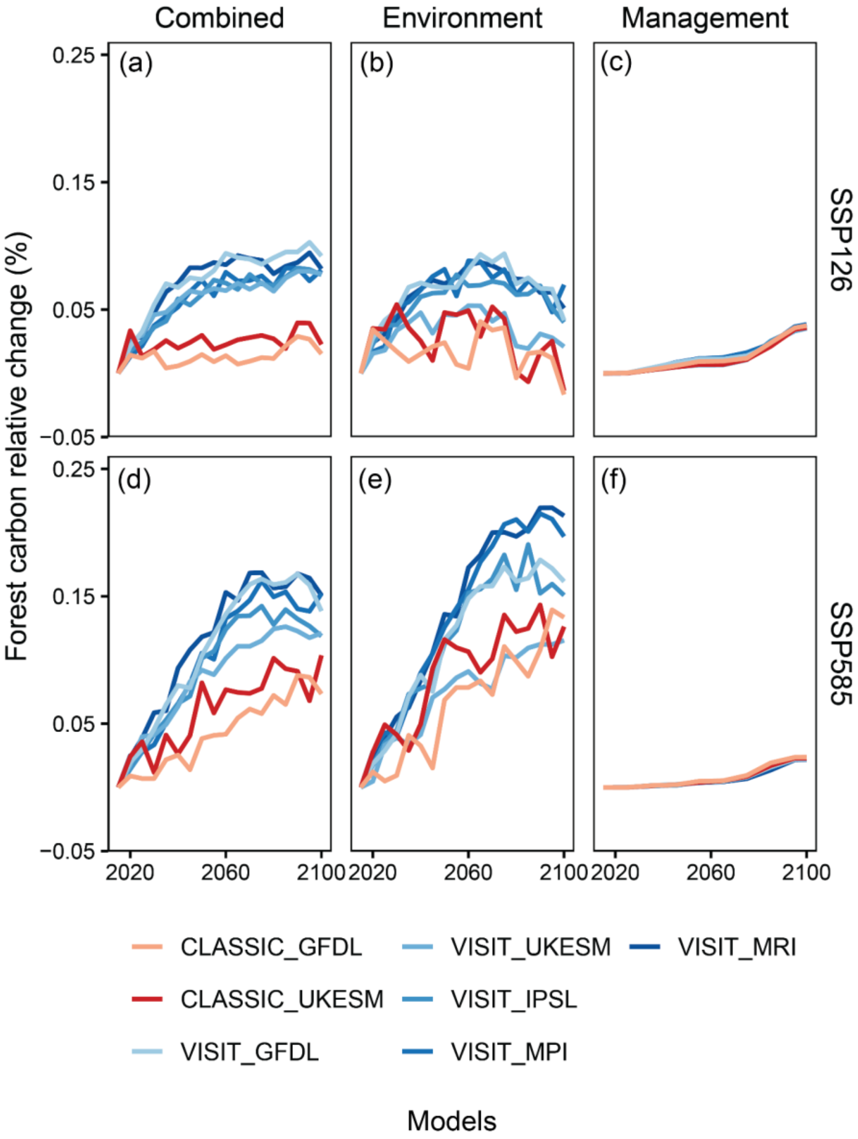

Fig. S5. Total forest carbon stock changes (vegetation + soil) under different TBM–ESM combinations from 2015–2100. Panels show (a,d) the combined effect, (b,e) the environmental change effect, and (c,f) the management change effect under SSP126 (top) and SSP585 (bottom). Line colours represent different TBM–ESM combinations. For combined and environmental effects, values are forest area-weighted global means; for management effect, values are managed forest area-weighted global means.

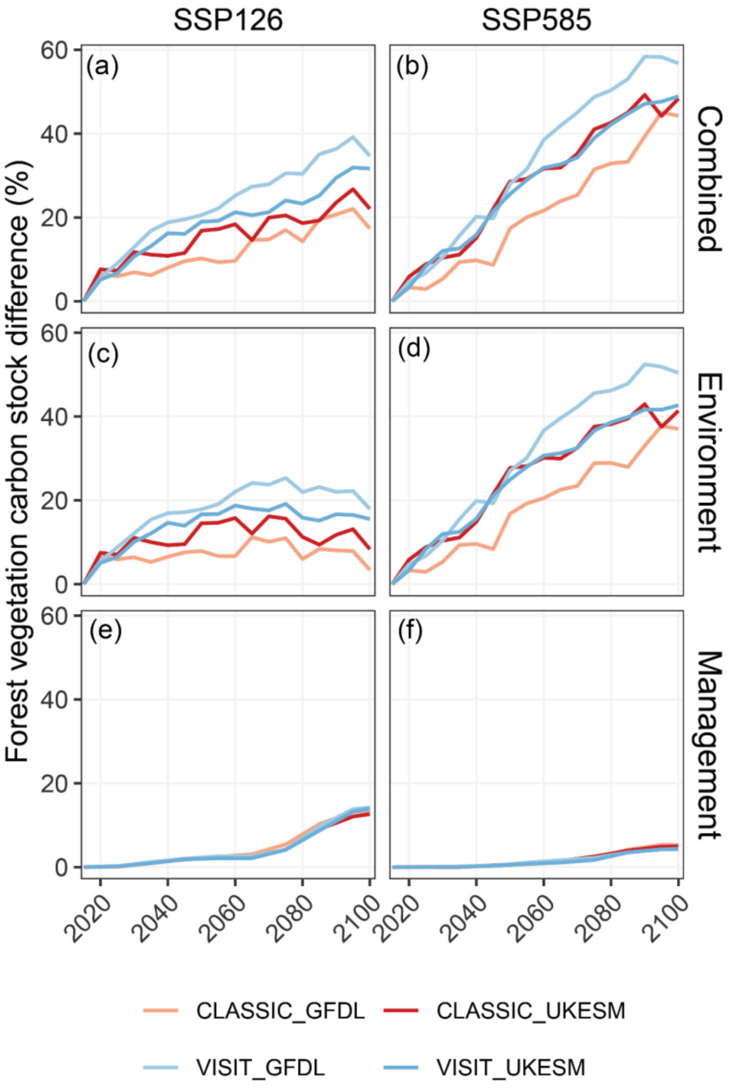

Fig. S6. Forest vegetation carbon stock changes comparing VISIT and CLASSIC from 2015–2010. Red represents CLASSIC simulations; blue represents VISIT simulations. Lighter colours indicate GFDL forcing; and darker colours indicate UKESM forcing. Panels show (a,b) the combined effect, (c,d) the environmental change effect, and (e,f) the management change effect under SSP126 (left) and SSP585 (right).

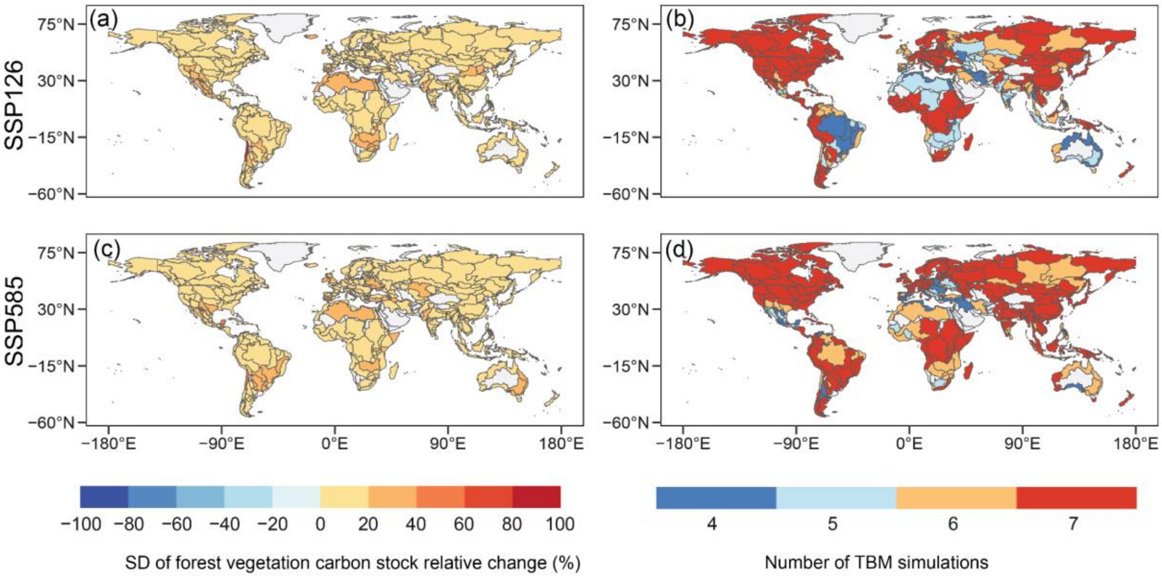

Fig. S7. Consistency and variability of forest carbon changes across TBMs. Panels (a,c) show the standard deviation of forest carbon changes (using VISIT simulations only), and panels (b,d) show directional consistency across all TBM simulation experiments, for changes driven by the combined effects of environmental change and forest management. Standard deviations are shown only for VISIT because the main-text results are based on ensemble means from VISIT simulations driven by five ESM climate forcings (and the corresponding VISIT-driven GTM and GCAM outputs). In contrast, consistency in the direction of change is evaluated across both TBMs (VISIT and CLASSIC) to assess sensitivity to TBM-related uncertainty.

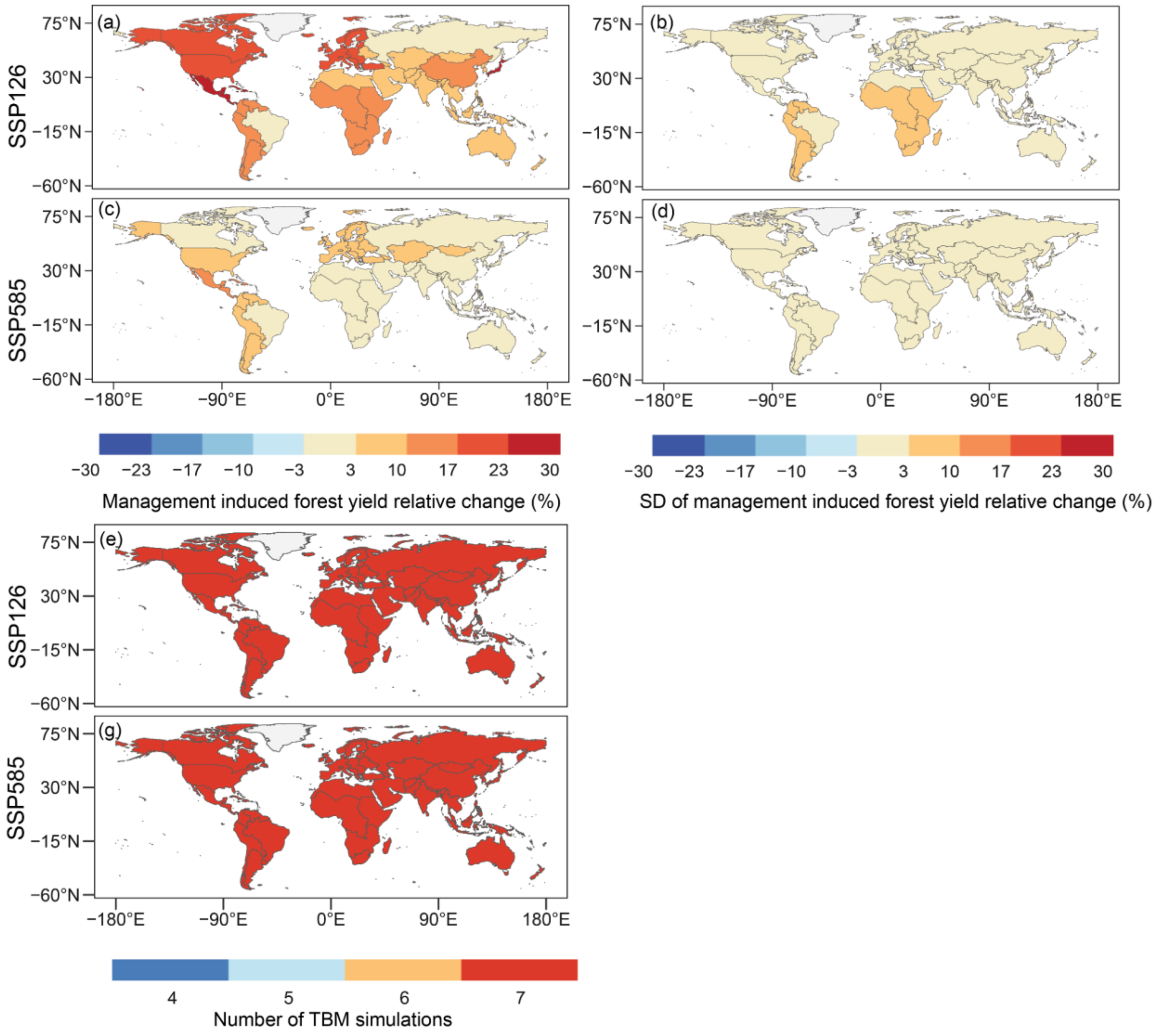

Fig. S8. Management-induced forest yield change under Envir_Manage, 2015- 2100. Panels (a,c) show mean yield change across TBM simulations. Panels (b,d) standard deviation across VISIT simulations. Panels (e,g) show directional consistency across all seven TBM simulations under Envir_Manage. Top row: SSP126; bottom row: SSP585. Standard deviation is calculated from VISIT simulations only, as main text results are based on VISIT ensemble means; directional consistency is evaluated across both VISIT and CLASSIC to assess robustness to TBM structural uncertainty.

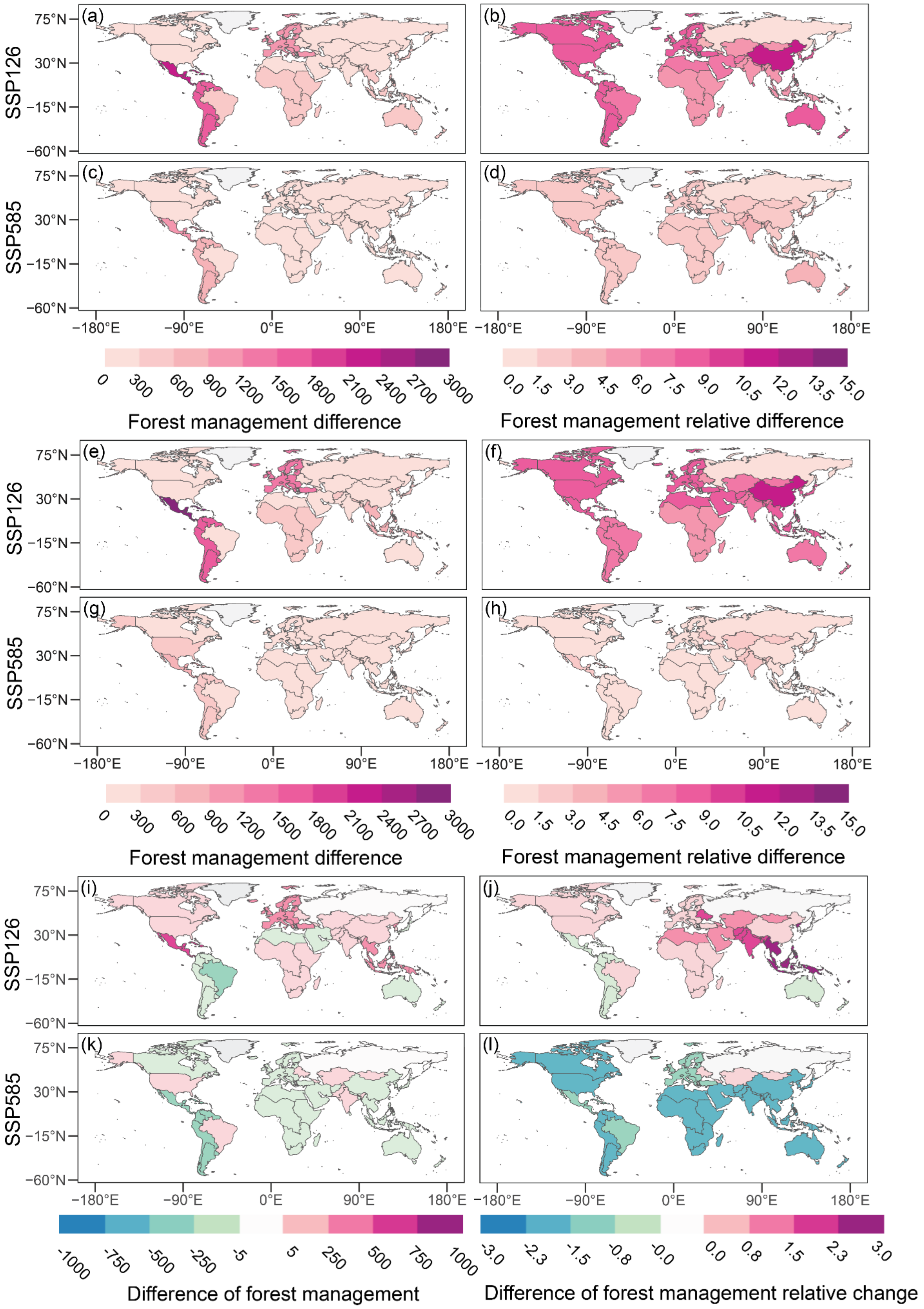

Fig. S9. Changes in forest management intensity for managed forests at mature age using VISIT-driven GTM simulations. Panels (a–d) show changes in forest management intensity from 2015 to 2100 under the *Manage_only* case, with absolute differences in panels (a,c) and relative differences in panels (b,d). Panels (e–h) show the corresponding changes under the

Envir_Manage case, with absolute differences in panels (e,g) and relative differences in panels (f,h). Panels (i–l) show the differences in forest management intensity between *Envir_Manage* and *Manage_only* by 2100 (i.e., panels e–h minus panels a–d), with absolute differences in panels (i,k) and relative differences in panels (j,l).

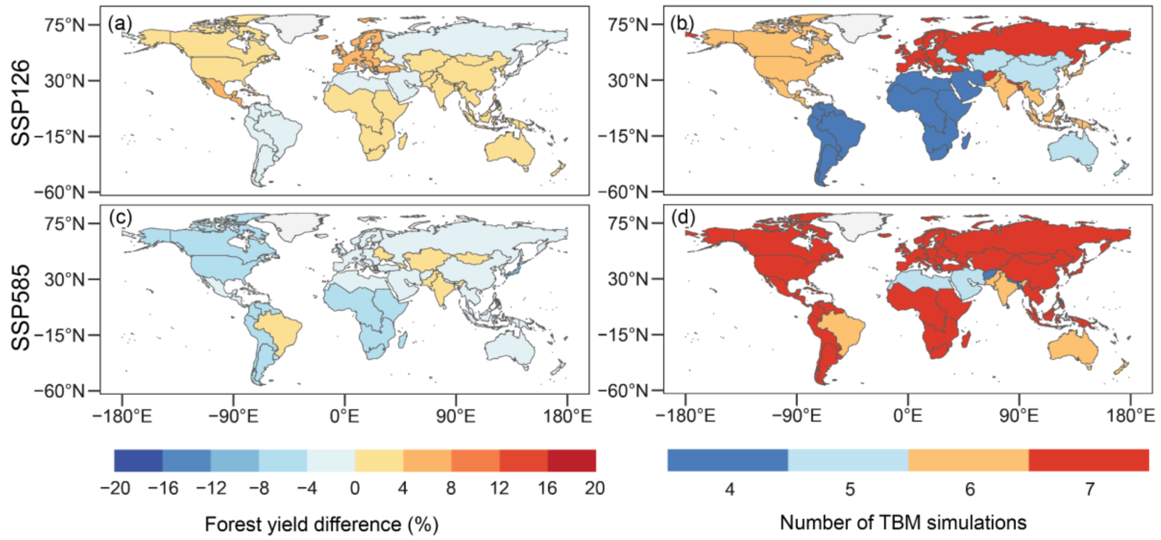

Fig. S10. Effects of environmental change on forest management outcomes across TBMs. Panels (a,b) show differences in mean values between scenarios with and without environmental change (i.e., *Envir_Manage* versus *Manage_only*) using different TBM simulations as inputs. Panels (c,d) show consistency in the direction of forest yield changes induced by forest management, comparing scenarios with and without environmental change across experiments using all seven TBM simulations under *Envir_Manage*. Standard deviations are shown only for VISIT, as the main-text results are based on ensemble means from VISIT simulations driven by five ESM climate forcings (and corresponding VISIT-driven GTM and GCAM outputs). Consistency in the direction of change is evaluated across both TBMs (VISIT and CLASSIC) to assess robustness to TBM-related uncertainty.

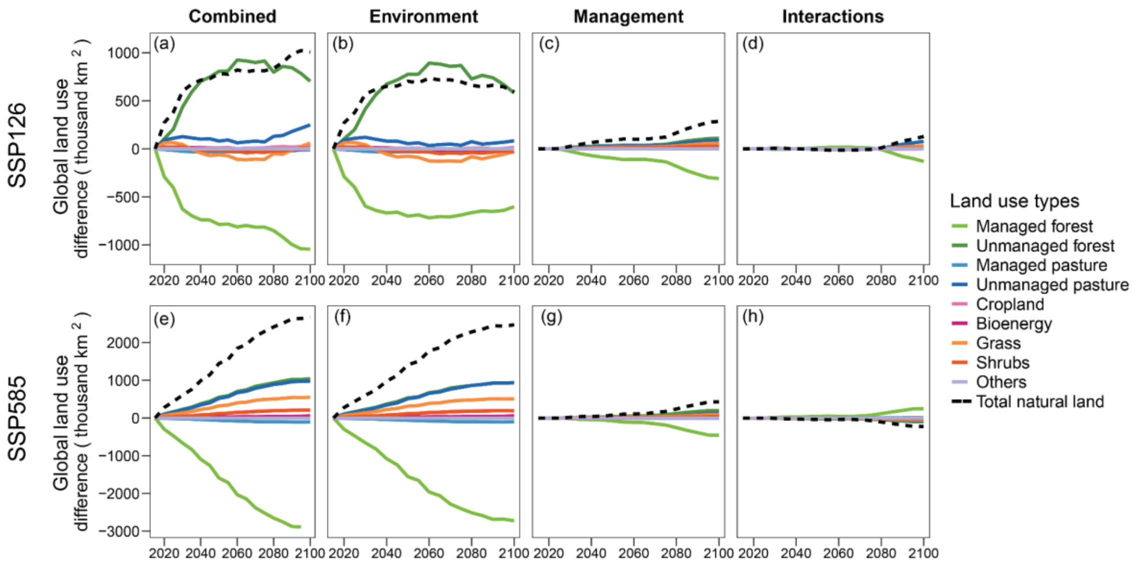

Fig. S11. Land use change differences induced by forest carbon changes driven by (a,e) the combined effects of environmental change and forest management, (b,f) environmental change alone, (c,g) forest management alone, and (d,h) the interaction between environmental change and forest management. Results are based on the mean values across simulations using different VISIT-driven GCAM simulations under (a–d) SSP126 and (e–h) SSP585.

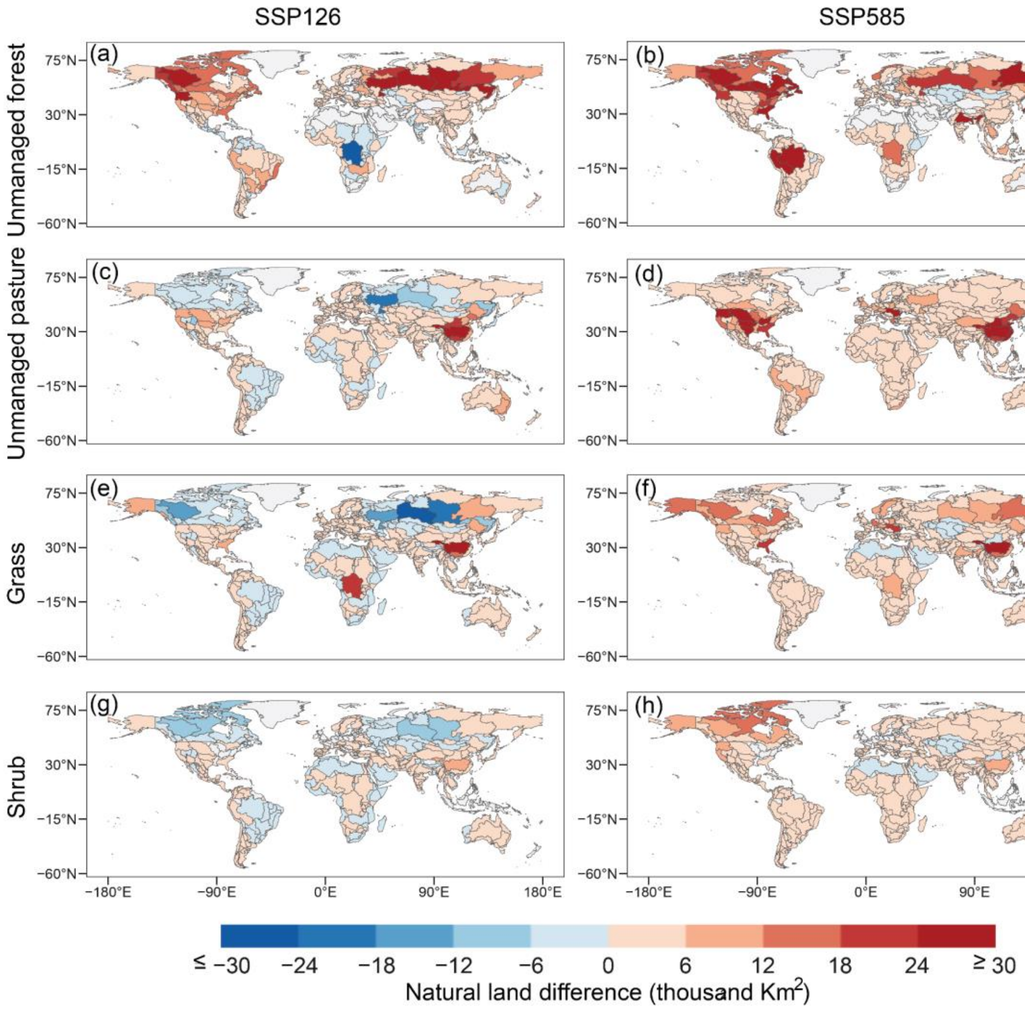

Fig. S12. Changes in natural land by detailed natural land use type driven by the combined effects of environmental change and forest management in 2100 under SSP126 and SSP585. Results are based on mean values across different VISIT-driven GCAM simulations, with panels (a,c,e,g) showing SSP126 and panels (b,d,f,h) showing SSP585.

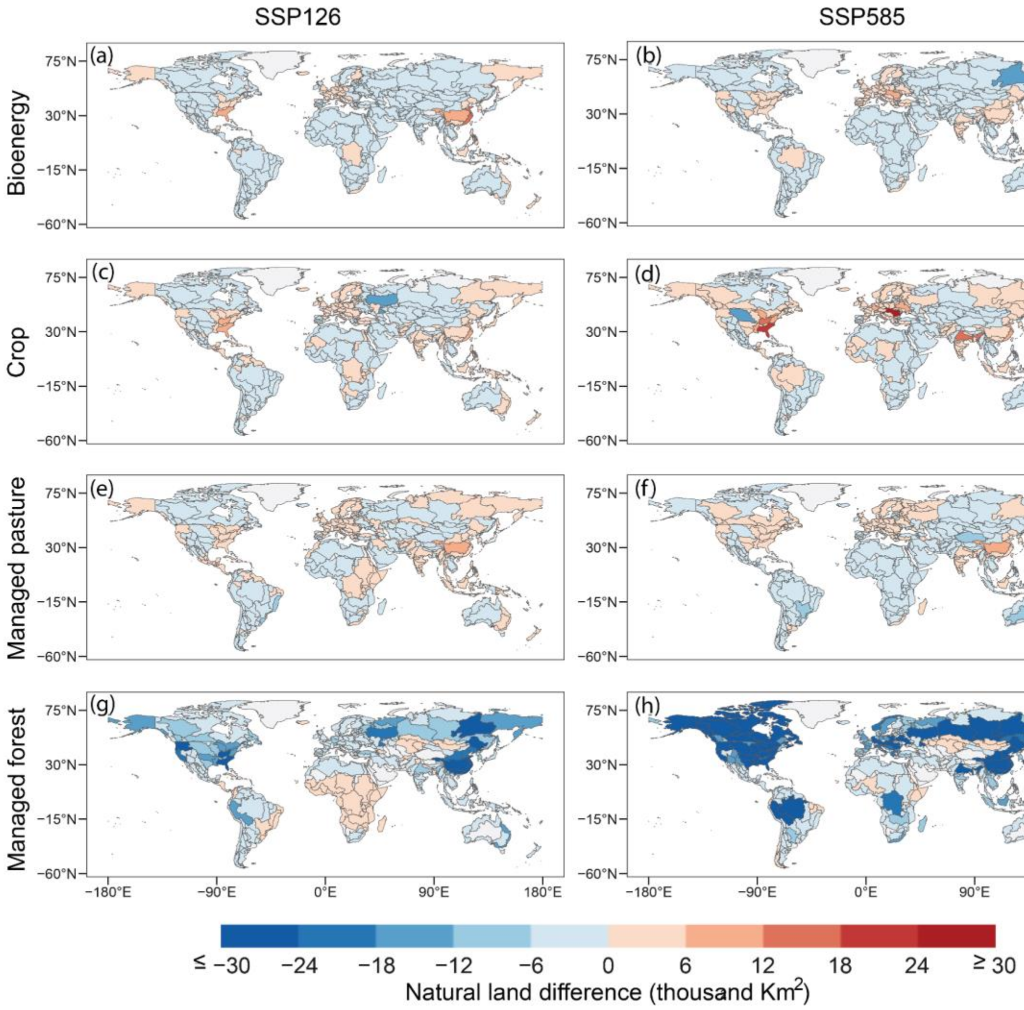

Fig. S13. Changes in managed land by detailed managed land use type driven by the combined effects of environmental change and forest management in 2100 under SSP126 and SSP585. Results are based on mean values across different VISIT-driven GCAM simulations, with panels (a,c,e,g) showing SSP126 and panels (b,d,f,h) showing SSP585.

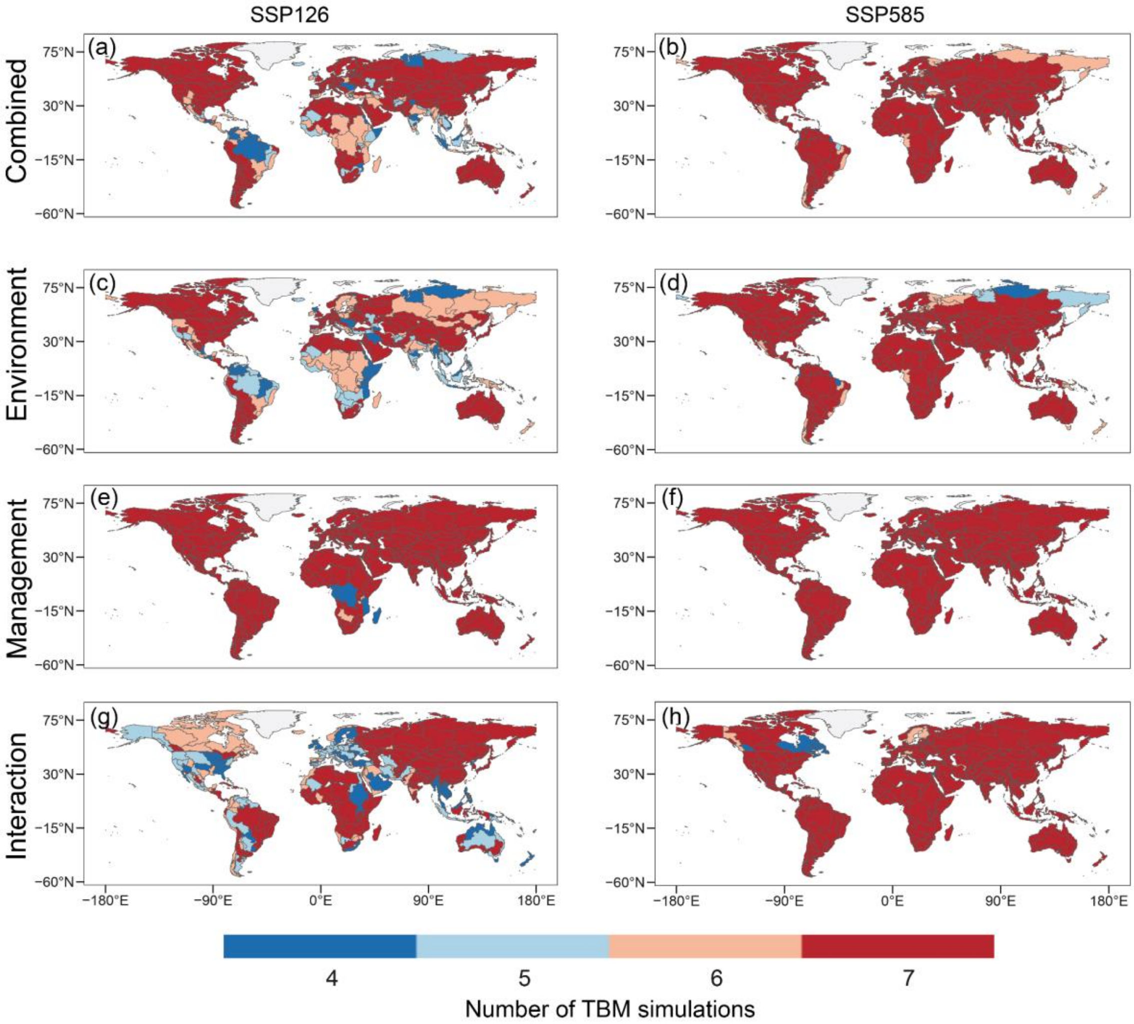

Fig. S14. Number of experiments using different TBM simulations that show a consistent direction of total natural land change in 2100 under SSP126 and SSP585.

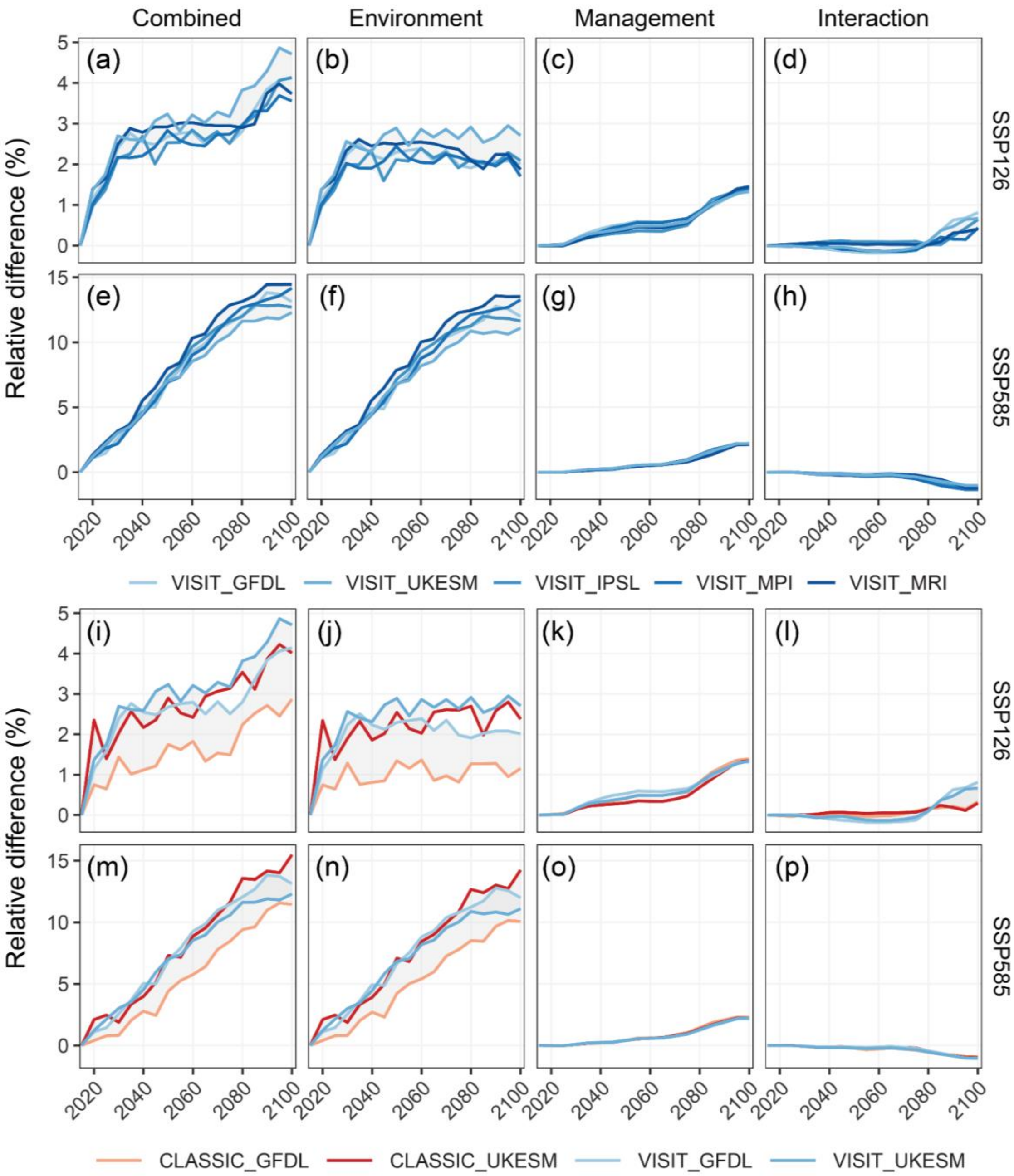

Fig. S15. Uncertainty in natural land change arising from carbon stock changes estimated using (a–h) different ESM climate forcings and (i–p) different TBMs. Colour tones distinguish simulations: red shades represent CLASSIC and blue shades represent VISIT, with lighter to darker tones corresponding to simulations driven by GFDL, UKESM, IPSL, MPI, and MRI. Panels (a–h) show results from the full ensemble of TBM–ESM climate-forcing combinations, whereas panels (i–p) show results from matched TBM–ESM simulations in which both TBMs are driven by the same ESM climate forcing. Panels (a–d) and (i–l) show results under SSP126, and panels (e–h) and (m–p) show results under SSP585. Panels (a, e, i, m) present the combined effect; panels (b, f, j, n) the environmental change effect; (c, g, k, o) the forest management effect; and panels (d, h, l, p) the interaction effect on natural land from 2015 to 2100.

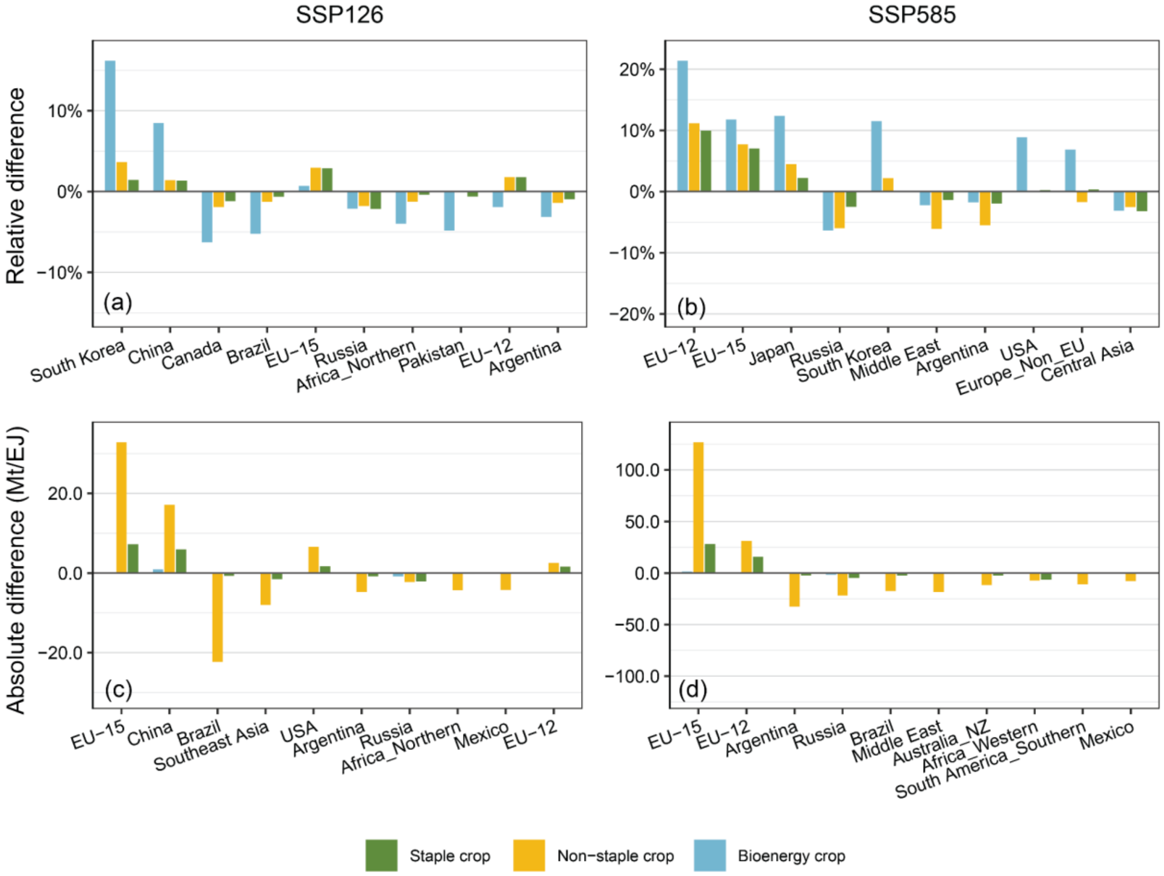

Fig. S16. Combined effects of environmental change and forest management on agricultural production, shown as relative and absolute changes (based on the ensemble mean of VISIT-driven GCAM simulations). Regions are ordered from left to right according to the summed absolute or relative differences across the three production types. Results are shown for the ten GCAM regions with the largest changes. Countries within each region are listed in Table S1, and the spatial distribution of GCAM regions is shown in Fig. S2.

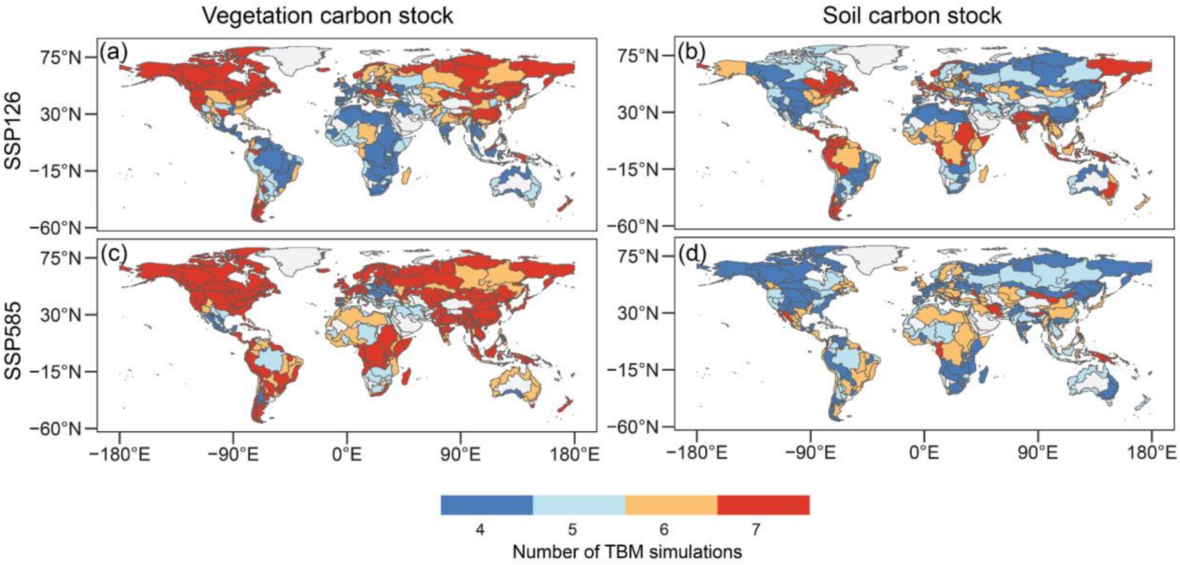

Fig. S17. Number of TBM simulations showing a consistent direction of environmentally induced relative change in forest vegetation carbon stocks (left) and forest soil carbon stocks (right) in 2100 under SSP126 and SSP585.

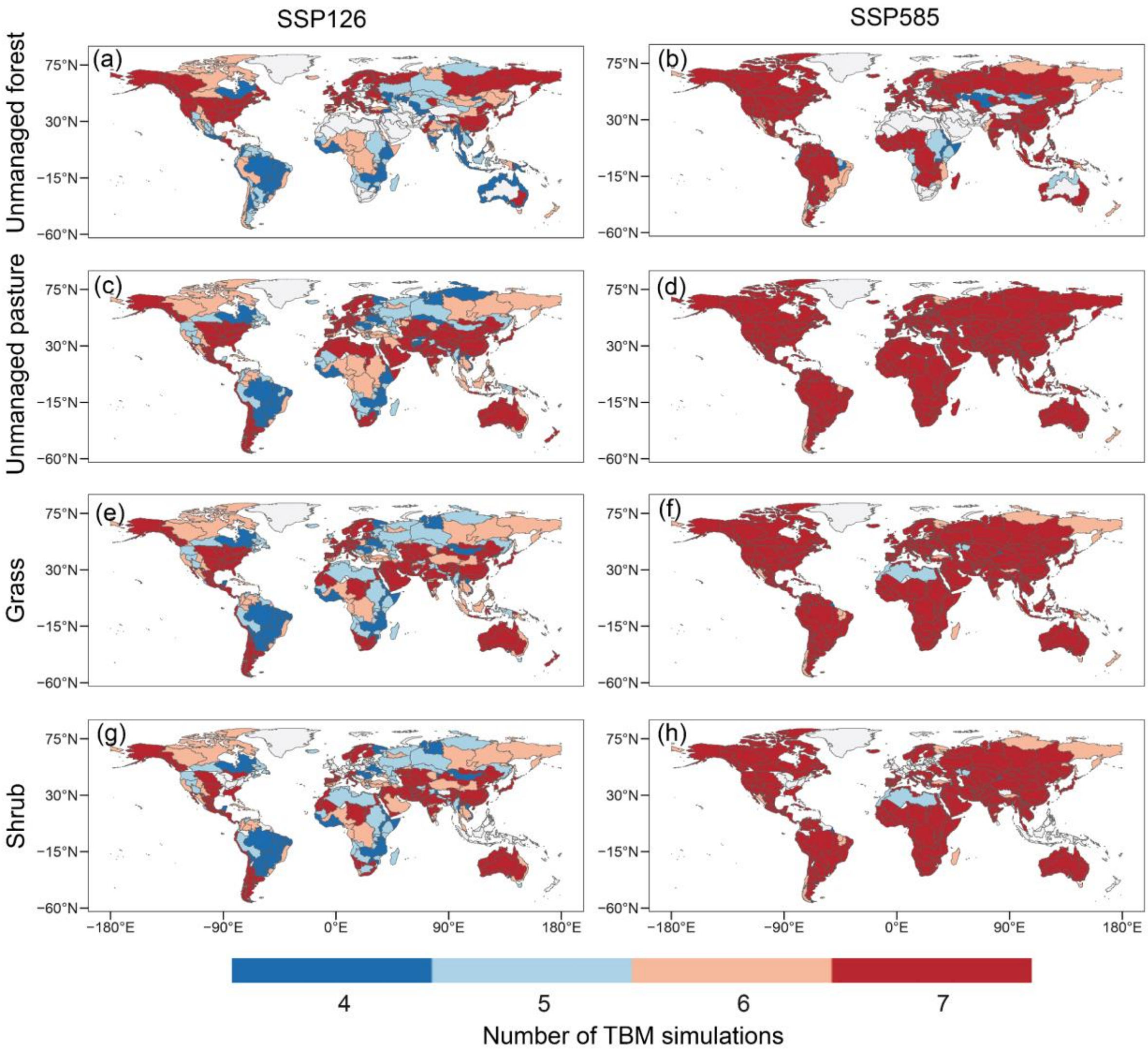

Fig. S18. Number of experiments using different TBM simulations as inputs that show a consistent direction of area change for each detailed natural land use type in 2100 under SSP126 and SSP585.

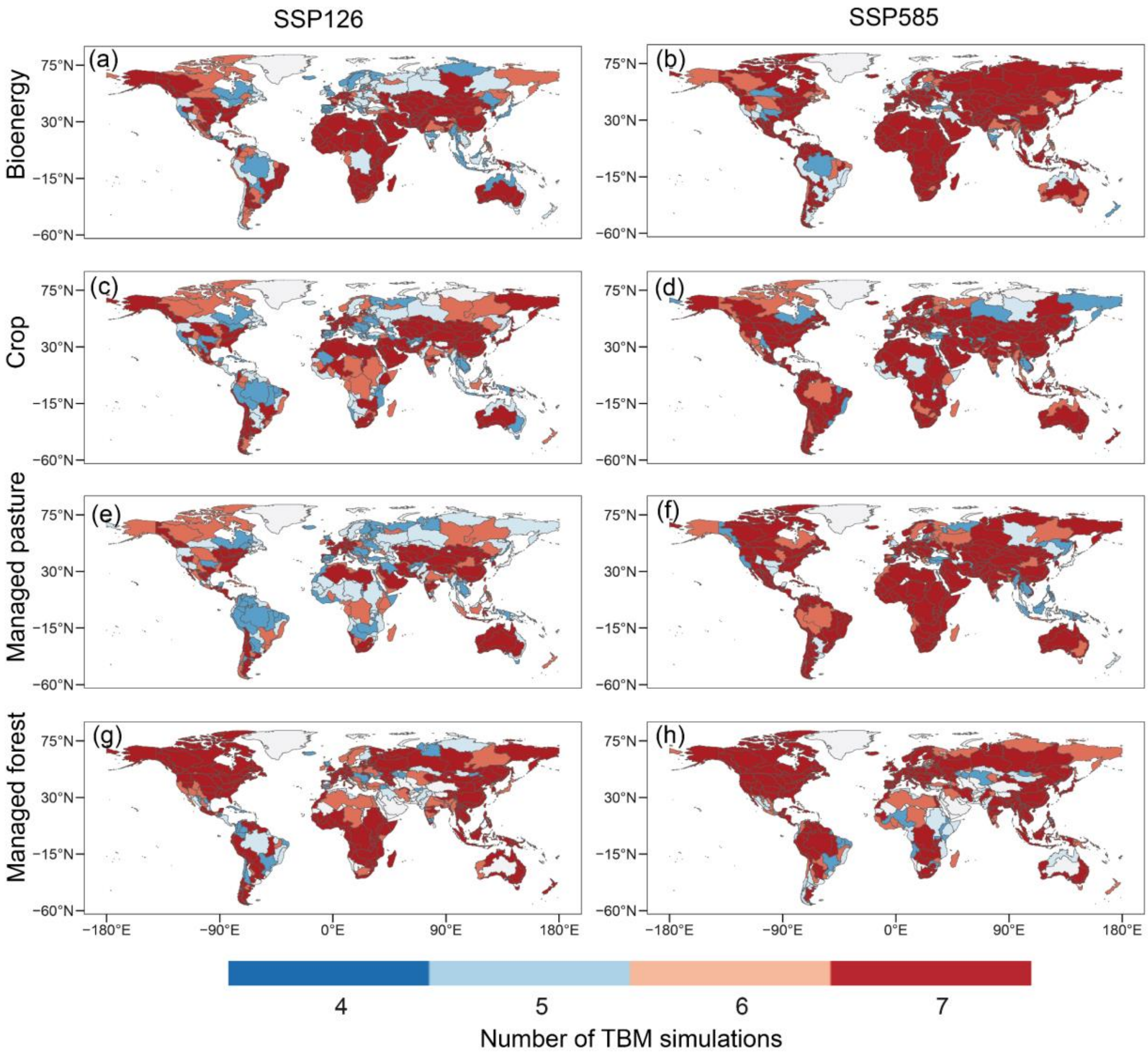

Fig. S19. Number of experiments using different TBM simulations that show a consistent direction of area change for each detailed managed land use type in 2100 under SSP126 and SSP585.

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